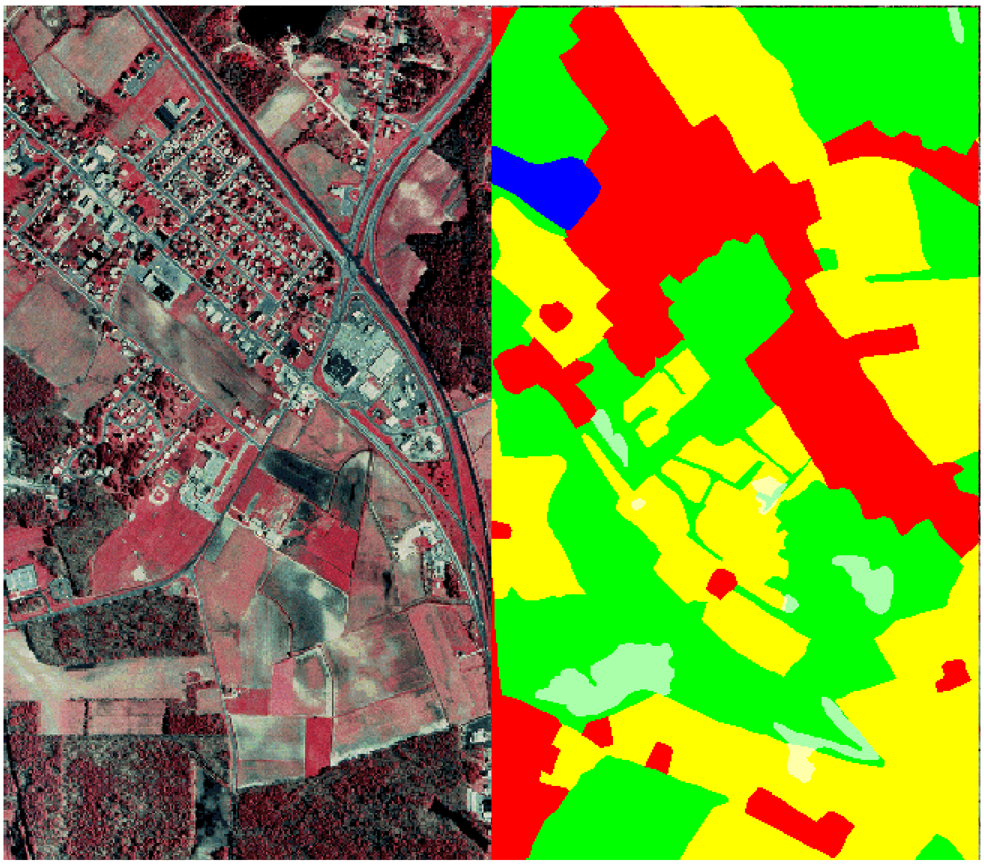
Report to the Chesapeake Bay Program Implementation Committee



The Feasibility of Producing Land Use and Land Cover Data with Wetlands and Riparian Forest Buffer Status and Trend Reports for the Entire Chesapeake Bay Watershed

DRAFT - March 30, 1999

SECTION I - EXECUTIVE SUMMARY

Issue

The Chesapeake Bay Program (CBP) partners have agreed that monitoring the status and trends of wetlands and riparian forest buffers throughout the Chesapeake Bay watershed is a program priority. This information is required to track progress toward specific wetland and buffer restoration and protection goals. The following paper proposes a way to meet these needs and describes significant ancillary benefits derived from a comprehensive program of land use and land cover mapping.

Background

This report is based upon an expert panel review of CBP needs and their suggested options to meet those needs. Panelists, including several national experts on land cover monitoring, were selected based on recommendations from CBP partners. The panel was briefed on CBP needs and on a wide range of land cover monitoring activities being undertaken by various CBP partners. These activities range from simply counting project-specific acreage from known wetland and buffer restoration gains and permitted wetland losses, to low-altitude aerial photography with inexpensive video cameras, to satellite-based systems that produce imagery using one or more fractions of the electromagnetic spectrum. Representatives of the CBP partner jurisdictions (except the District of Columbia) participated in the review. This report reflects a consensus of those representatives.

General Findings and Recommendations

Project-specific tracking, while valuable, provides an incomplete record of wetland and riparian forest buffer gains and losses. Therefore, a monitoring system that includes the analysis of remotely sensed imagery for the entire basin should be considered. In addition, we must take advantage of existing efforts to minimize the costs to the CBP.

While high-resolution imagery (e.g., aerial photography) and highly detailed resource mapping is desirable, image processing and data management costs would be prohibitive. Therefore, CBP partners should seek a compromise between image resolution (i.e., the smallest wetland or buffer area detectable) and cost.

Using current remote sensing techniques and available imagery, forested wetlands and narrow riparian forest buffers often cannot be differentiated to the high level of precision being requested by the CBP partners. Therefore, the CBP partners should cooperate with agencies (e.g., Department of Defense and NASA) who have expressed a strong interest in research and development of cost-effective remote sensing technologies to create ***practical*** solutions for applications in the Chesapeake Bay basin. As technical advances in this area are proven effective, their addition to the CBP monitoring system should be considered.

Recommendations for Wetlands

The U.S. Fish and Wildlife Service's National Wetlands Inventory maps have some limitations (e.g., omission errors in identifying certain types of forested wetlands), but they provide a valuable baseline map which, for wetlands monitoring purposes, can be updated using remote sensing techniques as well as project-specific tracking data available from the States and the Army Corps of Engineers.

Landsat-TM imagery is a readily available and relatively low-cost data source for determining when NWI maps require updating. Using a technique called Cross Correlation Analysis on the Landsat-TM imagery will cost-effectively identify areas experiencing change in wetlands. Thresholds can be established that will “trigger” the updating of the NWI maps to obtain a new inventory that can be used to determine the reasons for the change. The estimated cost for performing the Cross Correlation analysis on the Landsat-TM imagery over the entire basin every 5 years is **$63,150.00** with an estimated cost of **$63,000.00** to update the identified NWI maps every five years, including ground-truthing.

Recommendations for Riparian Forest Buffers

The CBP has a basin-wide inventory for riparian forest buffers that was produced by Pennsylvania State University. It is based on Landsat-TM imagery and provides statistically useful information on 100' and 300' riparian forest buffers that can be used for Bay Program management needs although it should not be used to provide information on a site-specific basis. This project demonstrated the need for a new large scale stream file for use in future CBP analyses. Regardless of our ability to identify land cover types from any image source, identifying riparian features is dependent on existing stream files that are all of questionable accuracy for these purposes. The CBP should explore the options and cost of developing a new stream file for the Bay watershed.

Project-specific tracking of buffer restorations will provide a valuable supplemental record of buffer gains. CBP partners should evaluate new image sources and methodologies, and repeat an appropriate buffer inventory every 5 years to assess basin-wide status and trends. The estimated cost for processing Landsat-TM imagery every 5 years is **$100,000.00**, including ground-truthing**.** Higher resolution image sources will cost more to acquire and process, but their use will allow a much higher confidence in the results and they will allow the identification of more narrow buffers than are currently detectable.

Ancillary Benefits to the CBP

Acquisition of Landsat-TM imagery and its interpretation for numerous other land cover classes (e.g., agricultural land, forests, urban) using conventional land cover classification methods will provide valuable data for use by CBP partners. These data are used for a number of natural resource restoration and protection efforts, and they are essential for assessing the impacts of growth in the watershed. For example, the CBP Wetlands Initiative is a tool for local governments to plan wetlands restoration and protection. Its implementation depends upon land cover data for not only wetlands, but for lands adjacent to wetlands. Up-to-date basin-wide land cover data will also be valuable for geographic targeting of CBP efforts in habitat restoration, small watershed assistance, and may be valuable in nutrient and sediment modeling and management. The estimated cost for processing Landsat imagery every 5 years for land cover classes and change analysis, other than wetlands and forest buffers, is **$219,300.00** including ground-truthing.

Infrastructure

There may be additional infrastructure costs for personnel, facilities, equipment and software depending on the extent to which these recommendations are implemented. The CBP should consider appointing a committee to determine the infrastructure needs, and their associated costs, for implementation of the selected recommendations.

SECTION II - BACKGROUND

"Torture data long enough, and it will confess." This statement is often heard among those individuals who are responsible for producing and analyzing spatial data products. It is easily applied to the forced use of data that is not appropriate for the intended purpose. Similarly, we have tortured the Chesapeake Bay Program participants so much about land use and land cover data that they have confessed to being confused. This confusion led to the creation of an Expert Panel that was convened on January 27 - 28, 1999, in Annapolis, Maryland. The panel developed a framework that provides the Bay Program with a cost-effective approach for creation of multiple land use and land cover data types, and status and trends information to meet the needs of the participants.

The goal of the Bay Program should be production of cost-effective, well documented and standard format, land use and land cover data products that can be used to analyze the condition of the watershed at scheduled intervals. However, there have been a series of "disconnects" between those persons who are expert at producing these products and their customers or the end users. This condition has existed for over ten years, and during this time, there have been a number of failed or inadequate attempts to initiate production of land use and land cover data. The Bay Program's end user community has developed exceptionally demanding requirements for remote sensing and monitoring of land cover, land use, wetlands status and trends, and riparian forest buffers. Realistically, these demands can not be met, but we can begin to meet with the end users to explain a practical framework for development of these monitoring efforts over the next ten years.

The capabilities of the Landsat satellite data and other remote sensing tools have been grossly oversold to those who need to use these data, creating an atmosphere of mistrust and false hopes. The tragedy of this situation is that when Landsat data are properly used and understood, they provide one of the few cost effective methods for deriving land cover data for an area that is the size of the Bay watershed. The legitimate question "will Landsat data meet all of the stated needs of the various workgroups in the Bay Program," still lingers and the answer is no. Classified Landsat TM data can meet the critical needs of the Bay Program and by incorporating a variety of remote sensing, monitoring and tracking schemes, the Bay Program partners can achieve most of their desired outcomes. However, accomplishing this will take an iterative process between remote sensing experts, data managers and the end users that will result in multiple resolution products and techniques. This document outlines both the suggested framework and an iterative process. It also clearly demonstrates that it will take a significant budget and people resources to mange this effort.

SECTION III - DEFINITION OF TERMS

For this document to be effective, we should first define several relevant terms in language that the non-technical reader can understand.

Land cover - is the condition of the land as it would appear to the eye. For example, the ground may be bare, or perhaps it is covered by trees, water, grass, agriculture or urban communities. Without ancillary data, one can not generally determine what use is being made of any particular land parcel. For example, is a forested area being managed for pulp wood, or is it in a natural state.

Land use - refers to man's particular use of the ground including such things as residential, industrial, institutional and commercial uses in an urbanized land cover, particular farming practices in agricultural covers.

Pixel - Every image is made up of a grid in which the individual cells represent a data observation. When aggregated and displayed at their proper scale, these individual pixels will represent an image. The pixel is the cell and is the smallest unit of an image that can be seen.   In this example (showing 5 x 5 pixels), the pixels are part of the image that is shown on the next page with the description of the minimal mapping unit. We have simply zoomed into the image to the point where the cells do not make "visual sense." The individual colors in these cells do represent a particular feature on the ground. In this case the dark pixels to the lower left represent trees and the lighter pixels to the upper right represent a grassy field. You will note the transitional area between these two distinct land cover types is represented by a mixture of shades. This "mixture area" is what typically defeats very precise classifications of satellite imagery.

Spatial Resolution - In the aerial photographic image above, each of the pixels represent a square on the ground surface that is 4 feet on each side. In Landsat imagery, the spatial resolution is 30 meters (98.1 feet) on each side which is equivalent to approximately 1/4 acre. Often, features that are smaller than the spatial resolution can be seen in particular types of imagery, because they have a unique reflectance that will cause the sensor in the satellite to record them. However, this phenomena or the ability to rely on the interpretation of one pixel have been grossly "oversold."

Spectral Resolution - Different remote sensing devices record the energy reflected back to them by features on the ground in different ways. The Landsat satellite's Thematic Mapper (TM) scanner records visible blue, green and red light along with near-infrared, two wavelengths of mid-infrared and a thermal band for seven separate digital files that can be analyzed separately, or together, to determine the nature of a feature on the ground. This is considered to be very good spectral resolution and results in the frequent use of Landsat TM data to identify land covers.

Change Detection - There are seven generally recognized methods of determining change in land cover and land use classifications from remotely sensed data. Two are commonly used. The first is **Multiple-date Change Detection Using a Binary Change Mask** which is a direct comparison of two time periods that results in a change map with summary statistics. This technique can be used in successive years, reduces change detection errors associated with incorrect initial classifications and results in a detailed "from-to" change analysis. The second method is **Post-classification Change Detection** which is widely used and easily understood. It provides good summary statistics for "from-to" change analysis for each time period. However, the analysis is very dependent on the accuracy of the two separate classifications. The Expert Panel favored multi-date change detection using a binary mask. While it is possible to detect some changes as small as one-quarter acre, the method is very reliable on changes of 2 acres and more.

Minimal Mapping Unit **-** The minimal mapping unit is the smallest area on the ground for which you will try to discriminate particular features. In the example at the left, the open field in the center of the image is approximately 4 acres. If we were mapping land cover in this area with a minimal mapping unit of 5 acres, we would not classify an isolated feature like this field and separate it from its surrounding land cover. It would be mapped as a forest land cover, because it is part of a larger forest area and below the threshold for mapping (5 acres). If this same field of 4 acres were adjacent to a larger agricultural area, (not located in a forest), it would be identified as part of that area, assuming that the aggregate area was over five acres. Theoretically, the smallest acceptable minimal mapping unit for Landsat TM imagery is 3X3 pixels or 1.99 acres. The minimal mapping unit size recommended by the Expert Panel was 5X5 pixels or 5.2 acres.

Temporal Accuracy **-** Every image is collected at a particular instant in time. When that image is classified, it represents the condition on the ground at that instant. Frequently, people tend to classify older imagery and then set out to ground-truth the results of the classification several years later in time. This practice can conclude in erroneous results when comparing the ground-truth data to the image classification.

Classification Accuracy **-** Classification accuracies are defined differently for the producer and the user of land cover data. Both are based on a comparison of ground truth results to the proper, or improper, classification of features in the imagery. The **user's accuracy** represents commission errors, or those points classified as a particular land cover that ground-truthing reveals are some other land cover. The **producer's accuracy** represents errors of omission, or points not classified as a particular land cover when ground-truthing reveals that they should have been included in that class. It is possible for the user’s and producer’s accuracies to be quite different for each particular land cover.

The two tables on the following page are typical of the ones produced during image classification for land cover. After ground truthing is completed, the results can be analyzed to determine accuracy figures. If the error rates are below the acceptable range, it is likely that additional time will have to be spent to reprocess the images with more supervision.

Classification vs Ground Truth Results

(The numbers in the bold italic font are where the classification and ground truth results agree. The remaining numbers in the chart are where classification and ground truth results do not agree. The Row and Column totals are used to determine user's and producer's error)

Land Cover Classifications are Below & G.T. Results are to right	**Urban** *Ground Truth*	**Agriculture** *Ground Truth*	**Deciduous** *Ground Truth*	**Coniferous** *Ground Truth*	**Water** *Ground Truth*	*Row Total*
Urban	***75***	2	0	3	5	85
Agriculture	3	***64***	4	0	4	75
Deciduous	1	1	***84***	5	4	95
Coniferous	0	2	4	***63***	1	*70*
Water	0	1	2	2	***40***	45
Column Total	79	70	94	73	54	370

User's and Producer's Accuracy Calculations

Land Cover	**Producer's Accuracy**	**User's Accuracy**
Urban	(75/79) x 100 = 95%	(75/85) x 100 = 88%
Agriculture	(64/70) x 100 = 91%	(64/75) x 100 = 85%
Deciduous	(84/94) x 100 = 89%	(84/95) x 100 = 88%
Coniferous	(63/73) x 100 = 86%	(63/70) x 100 = 90%
Water	(40/54) x 100 = 74%	(40/45) x 100 = 89%
	The above percentages were calculated by dividing the # of correctly classified points according to the ground truth by the **column total** and multiplying by 100 to get a percentage	The above percentages were calculated by dividing the # of correctly classified points according to the ground truth by the **row total** and multiplying by 100 to get a percentage

SECTION IV - "CHARGE" AND USER NEEDS PRESENTED TO THE EXPERT PANEL

The Expert Panel was briefed on their "charge" and given information about the various requirements of the user groups within the Bay Program. Their charge was to determine "The best Land Cover Monitoring System, including imagery and Land Cover classifications, that will meet Chesapeake Bay Program needs within practical constraints." The following requirements were included for the Panel's discussion:

- Achieve an 80 to 90% accuracy rate for classes that the Program cares about,
- Detect changes as small as 5%,
- Design a system within a reasonable cost,
- Design a system that is repeatable every five years,
- Make certain that the system is adaptable to future technologies, and
- Suggest staffing needs to maintain a Land Cover and Land Use mapping program.

Wetlands - This workgroup wants to establish a baseline by year 2000 with status and trend reports every five years afterward. They wanted a 30 meter minimum resolution with a resolution as high as 1 meter. They also want to use NOAA's Coastal Change Analysis Program or the USFWS's National Wetlands Inventory classification systems with ground truthing. It is important to this group that they be able to determine the surrounding land covers.

Riparian Forest Buffers - This workgroup wants a tracking system that will monitor progress toward the goals established for 35' and 100' buffer creation. They believe that they need to integrate their data into a basin-wide land cover mapping system on a 10-year interval.

Forests -This workgroup asked for a resolution between 10 and 30 meters. The group wants to monitor the areal extent of deciduous, coniferous and mixed forest covers. They also need to integrate this information into a basin-wide land cover mapping system on a 10-year interval.

Nutrient Reduction/Tributary Strategies - This workgroup wants to monitor land cover and land use changes every 5 years to determine the impact this change has on the 40% nutrient reduction strategy. They have asked for 15 meter or larger resolutions to obtain the data for their modeling efforts.

Land Growth and Stewardship - This group needs to monitor land cover and land use changes over the entire basin every 5 years. They have asked for imagery between 1 and 30 meters to accomplish their goals which include identifying preserved agricultural lands, recreation and open spaces, land trusts and conservancies, and urban development.

SECTION V - DEVELOPING A LAND COVER DATA SET FOR THE BAY WATERSHED

The Bay Program can easily develop a mapping program to create reliable and repeatable land cover data to produce management and trends analysis information, as well as data for computer model input. However, the Expert Panel felt that the stated objectives of the user community can not be met in a cost effective or timely manner. It is not clear that the user community understands the relationship of their accuracy and minimal mapping unit requirements with regard to the trend information or model input data that they are seeking. For example, the State of Maryland (approximately 10,700 square miles) has planned for and managed their growth over the past twenty years using land use and land cover data that has a minimal mapping unit of 10 acres. While not ideal for many localized studies, the data have been produced at relatively low cost and provide the required management information to determine trends in growth. In the absence of more detailed information, the data are also used in modeling efforts. In contrast, some of the Bay Program's workgroups have requested data with a minimal mapping unit as small as 1/16 acre for a watershed that encompasses an area of approximately 64,000 square miles!

With few exceptions, satellite imagery can not determine land use, however, the Landsat TM sensor is particularly well suited for determining land cover. The expert panel recommended a **cost-effective** approach using an appropriate classification of Landsat TM imagery to develop land cover data. The new Landsat VII satellite should be launched in April of this year. It returns the control of the Landsat TM data to government agencies and will reduce the price of each scene from over $4,500.00 to approximately $450.00. This is an important factor, because the most accurate classifications of TM data are obtained by using two or more scene dates to classify those hard to identify land covers.

There are potential cost savings by building off of the federal government's Multi-Resolution Land Cover (MRLC) 2000 classified imagery as recommended by several panel members. At several discussions of the land use and land cover needs held in the past two years, state representatives from Virginia and Pennsylvania emphasized that classification of land cover throughout their jurisdiction, not just the Bay basin, would greatly increase their commitment to the product. By using MRLC as the base of our wall to wall coverage, we can get jurisdiction-wide coverage directly and consistent with the Bay watershed coverage which will undergo more detailed ground truthing and classification using supplemental data sources. By partnering with the MRLC program, the Bay Program may get classified land cover data at lower costs every ten years and access to geo-registered scenes in the in-between five year interval. This may save the Bay Program partners significant funds. We need to determine the timing of MRLC 2000 and line up the Bay region to be the top priority. We also need to work with the MRLC program to obtain a classification classification system that is consistent with the needs of the Bay Program.

The expert panel recommended that the Bay Program begin their year 2000 baseline land cover map by processing Landsat TM scenes according to the following criteria.

Minimal Mapping Unit - 5.2 Acres (5 x 5 or 25 pixels)

Time Periods - Each classification shall use at least two time periods including one growing season and one leaf-off period

Classification System - Anderson Level I with inclusion of some Level II categories (or equivalent) according to the following schema

Level I	Level II
1. Urban	
	11.Low Density (not Anderson)
	12. High Density (not Anderson)
2. Agriculture	
	21. Crop land
	22. Pasture

4. Forest
    41. Deciduous Forest
    42. Coniferous Forest
    43. Mixed Forest
    44. Brush or Scrub/Shrub
5. Water

6. Wetlands (Limited to non-forested, including tidal flats and marshes)
7. Barren Land
    74. Rock
    76. Transitional (clear cuts, drained wetlands, fill areas, bare soil)

Classification Accuracy - User's and Producer's Accuracy >80% for each Classification

Ground Truth - To Be Designed (will include use of existing orthophotos)

Frequency or Repeat Time - Every five (5) years

Change Detection - Multiple-date Change Detection Using a Binary Change Mask (Recorded for 3 x 3 or 9 pixels for 1.99 acres). Will detect average change >5% in all classes.

Cost for Above - 17 Scenes in Bay Watershed x 2 time periods/scene = 34 Scenes x $450.00 = $15,300 (continued)
Approximate Cost of $12,000 per 2 scenes for processing and ground-truthing = $204,000.00
Total Cost = $219,300.00/each 5 year period. This cost estimate is for private sector contracting.

SECTION VI - DEVELOPING A WETLANDS STATUS AND TRENDS REPORT FOR THE BAY WATERSHED

Cost-effective identification of palustrine wetlands is very problematic when using current remote sensing and image processing technologies. Many reports have been produced which document the particular difficulty of identifying palustrine forested wetlands. Much of the research has been conducted in Wicomico County, Maryland, where reference sites have been established. Again, the stated needs of the Wetlands Workgroup for 1/4 acre change detection and classification are far beyond what the producer community can accurately deliver. A consensus building exercise should be undertaken between these two groups.

Wetland gains are caused by mitigation, construction projects that alter hydrology, sea level rise, land subsidence and accretion. Wetland losses, or conversion of types, are attributed to construction activities, sea level rise, land subsidence, erosion, and changes in hydrology. In general, all of these losses and gains are extremely small in magnitude when compared to the total surface area of the Bay Watershed.

Each of the states involved in the Bay Program submitted a plan in response to the Executive Council's directive 97-2 regarding strategies for wetlands protection and restoration goals. Each state presently tracks the location of mitigation sites for permitting purposes and they can report the gains on a geographic and quantitative basis. Significant gains of tidal wetlands, due to the remaining factors, will likely be seen over long periods of time by using a standard land cover classification as previously described. The emphasis on ***long periods*** of time is due, in part, to the difficulty in controlling tidal stage during image acquisition. Classifying imagery from different time periods with different tidal stages will lead to erroneous results in the short term that have to be closely evaluated. However, over a long time period (15 - 30 years), there should be little doubt about the gains caused by these remaining factors.

A new method exists for the determination of wetland losses in areas where digital map data exists. The entire Bay Watershed has been mapped by NWI and nearly all is available in digital form. The method is known as Cross-Correlation and it was developed by EarthSat Corporation in Rockville, Maryland. Its development was conducted in cooperation with the National Wetlands Inventory (NWI) and the Environmental Protection Agency and the technique has gone through significant peer review and in-the-field evaluation. All of the following three paragraphs is taken directly from the EPA's Wetlands Home Page, except the cost estimates. The cost estimates have been developed in conjunction with the drafting of this plan.

The technique involves processing of Landsat TM data two times. In the first pass, the mean and standard deviation for each wetland type delineated on the NWI maps is calculated for all or a selected subset of Landsat TM bands. A single wetlands map may have over 200 different wetland types, where each wetland type is a unique combination of system, subsystem, class, subclass, and modifiers of the wetlands and deep water habitats classification system (Cowardin et al. 1979).

In the second pass a "Z-Statistic" is calculated for each Landsat TM pixel that corresponds to a wetland pixel from the NWI digital data set. The Z-Statistic is computed by calculating the sum of the normalized differences between the means of the Landsat TM bands for the wetland type and the actual Landsat TM values for the pixel. High Z-Statistics indicate dramatic changes in wetlands. Low Z-Statistics indicate no wetland change. The user will interactively determine the Z-Statistic threshold which indicates significant change on a region-by-region basis.

Operational implementation using Landsat TM scenes would quickly and inexpensively identify where wetlands mapped by the NWI have changed or have been destroyed. A single Landsat TM scene covers more than 200 full 7.5 minute U.S. Geological Survey quadrangle maps (the base map used for all NWI maps) and can be used to appraise the extent of wetlands changes and losses occurring on over 200 NWI maps. The wetland changes and losses can be plotted at a scale of 1:24,000 and overlaid on the original NWI map to provide location information for navigating to the sites for field investigation. This service (cross-correlation and change maps) is commercially available for approximately $50.00 per quad or $63,150.00 for the entire watershed (based on 1,263 quads in watershed).

The Bay Program's activities will have to be integrated into NWI's mapping program to be fully effective. Cross Correlation will identify areas of loss and in limited cases, addition through pond construction. The NWI has decided that on map sheets with the lesser of the following parameters, (5% change in wetland acreage, or 5% change in number of polygons, or 350 acres total wetland change), they will update their standard map product. Therefore, Cross Correlation triggers a map update at a cost of approximately $1,000.00 per sheet. The NWI does not expect to see more than 5% of the map sheets require modification in any given year. The overall cost of map maintenance should be factored at approximately $63,000.00 per every five years. In addition to this trigger, individual state permit and mitigation tracking databases should feed information to the NWI to be used when updates to the map sheets are made. This same kind of program has been called for in the following KEY ACTION item taken from the Clean Water Action Plan.

> "KEY ACTION: The White House Wetlands Working Group will, by October 1999, establish an interagency tracking system (based on the wetlands layer of the National Spatial Data Infrastructure) that will more accurately account for wetland loss, restoration, creation, and enhancement. This task will include establishing accurate baseline data for federal programs that will contribute to net wetland gains. The system will be peer reviewed."

The infrastructure required to facilitate this two-way exchange of information will have a cost that is unknown at this time, however, it will not be insignificant.

SECTION VII - RIPARIAN FOREST BUFFERS

The user requirements for monitoring riparian forest buffers were provided to the Expert Panel. First, natural buffers that are greater than 100 feet wide need to be inventoried. The second requirement is to monitor created buffers greater than 35 feet in width. After a lengthy discussion, it was determined that the agencies working to create riparian forest buffers were maintaining databases that would provide suitable information on the created buffers. These buffers are far smaller than the reliable detection limits of Landsat imagery.

Riparian forest buffers greater than 100 feet have some likelihood of being detected during classification of Landsat imagery. These features will only occupy one pixel in the Landsat imagery, and as previously stated, a feature must occupy at least 3 x 3 pixels to be reliably located. In addition, to locate riparian forest buffers in digital imagery, one needs a digital stream file. There are no basin-wide large scale stream files available for this analysis and the existing files all have known inaccuracies related to precision of the stream location. The image to the left demonstrates this problem. At this location, the digital stream is from 148 to 480 feet to the right of its true position which is in the dark forested area. While this type of inaccuracy is not typical, it does clearly represent this problem which is frequently found to lesser extents. Therefore, as we push classification of the satellite imagery to the maximum possible extent and compare it to stream files of doubtful quality, we obtain erroneous data. This results in

relatively low user's and producer's accuracy from a mapping standpoint. The Expert Panel did not have a "feeling" for the existing accuracy assessments of linear features equal to or less than 100 feet. However, few people expected to achieve better than a 50% accuracy rate for linear features of this width. This is clearly an area for operational research and development using higher resolution satellite or airborne imaging systems. For example, the IKONOS satellite to be launched on April 12, 1999, will have a 4-meter resolution multispectral scanner that may provide the data required to conduct analysis of 35' and wider riparian forest buffers. Based on previous experience, the cost to produce a forest buffer inventory will be approximately $100,000.00.

As already noted, the need to produce an accurate inventory of forest buffers highlights one of the most basic spatial data needs of the Bay Program. A large scale stream file must be produced for the entire Bay Watershed to properly conduct this effort and to support the increasingly sophisticated analyses that will be required to support future planning activities. Without this file, it is literally impossible to produce precise map analyses related to stream features. The Pennsylvania State University report states that "The streams coverage for the bay watershed used in this project had obvious inconsistencies in scale, density and accuracy that may have impacted the results. Improved streams coverages should be produced and used in future analyses. Stream attributes characterizing the stream type, size etc. should be added to the coverage. Land use data is available for the Bay as part of the MRLC program and should be evaluated as an improved land use coverage. Watershed boundaries (11-digit), which currently do not edge-match correctly at state boundaries should be improved." This should become a high priority action item for the CBP.

In the interim, the Expert Panel recommended that the States provide geocoded information on created riparian forest buffers to the Bay Program for inclusion in the recommended land cover data system. In addition, the Pennsylvania State University Riparian Forest Buffer Inventory can be used for its statistical information as a starting point baseline from which to manage forest buffer issues basin-wide. This provision is made, because the verification study supports its statistical validity and it represents the only consistent product produced over the entire basin.

SECTION VIII - DEVELOPING A LAND USE DATA SET FOR THE BAY WATERSHED

Generally speaking, land use classifications can not be determined from satellite imagery using automated technologies or data that are currently available to the civilian sector. Examples of land use classifications that are important to the Bay Program include a breakdown of residential, commercial, industrial and institutional uses within an urban land cover. Accurately determining these classifications requires intimate local knowledge and human interaction during the classification process. This obviously comes at a relatively high expense. Digital alternatives do exist when geo-referenced parcel and other ancillary data are available.

The Expert Panel discussed two alternatives for production of land use data for the Bay Program. First, we could work with tax assessors or other local officials (fire department personnel) in each county to obtain an x and y coordinate for each parcel in the Bay watershed. Presumably, the Bay Program could fund handheld GPS units for each county's use and assist with database modifications, so that during the triennial assessment process or during fire planning activities, local officials could obtain the coordinate information. Within a four to five-year period, we could obtain data that would allow an accurate classification of land use during the first repeat cycle. The second alternative is to begin a research program with the Bay Program's DOD partners, other federal agencies and the private sector to develop remote sensing applications (satellite and airborne) that can better determine land use classifications. This option is obviously risky, because it could set up an endless research loop. It is clear that no remotely sensed data will provide the ability to determine land use categories equivalent to Anderson Level III, however, land uses of the type needed in the Bay Program may be obtainable through the appropriate application of remotely sensed data. The benefit of selecting option one is that it would establish a working relationship between the Bay Program and every county in the Watershed. In addition, many counties will likely use this new information to assist in their various management activities including parcel assessment or E911 addressing.

Production of accurate land use information is costly in terms of both operating budget and personnel time for any possible production scenarios. Cost factors for development of a land use mapping program can not be accurately estimated until the Bay Program workgroups finalize their needs. The Expert Panel recommended that certain areas (e.g. urban centers) be specifically targeted for production of detailed land use information. This would prevent the Bay Program from wasting funds while pursuing wall to wall coverage of land use data in the entire watershed. The Bay Program will have to provide further coordination between the work groups to precisely determine their needs. The Expert Panel recommends that work on a land use database be delayed until a consensus is obtained among the work groups and that the alternatives are researched appropriately to ensure they will mesh with the remaining efforts.

SECTION IX - PROPOSED TEST OF LAND USE AND LAND COVER DATA

As stated earlier, data producers and users need to engage each other in an iterative approach that will strike a balance between needs, capabilities and cost. To this end, the Expert Panel determined that Maryland is creating a 1:12,000 scale land use and land cover data set for the entire Pocomoke River watershed and Maryland's portion of the Coastal Bays watershed. The Panel felt that these data should be compared to existing smaller scale land use and land cover data in the commonly used modeling packages. This comparison will provide an opportunity to determine if modeling results are significantly different based on higher precision land use and land cover data. The results of this comparison may relax some of the user requirements, thereby reducing land use development costs.

The Expert Panel recommended assigning this activity to the Chesapeake Bay Program's Modeling Subcommittee for follow-up when the data become available from Maryland DNR. The results of the modeling comparison need to be carefully evaluated between the producers and users for trends and to develop additional specifications for production of the land use and land cover data. After this comparison, new land use requirements can be developed.

SECTION X - INFRASTRUCTURE

In order to engage all of the Bay Program partners in this endeavor, it is imperative that a core group be established that includes at least one representative from each state, and from each of the committees that want to use the data produced under this proposal. This group should invite private sector companies to their meetings which should be held jointly with the GIS committee. Many data system issues need to be researched prior to installation, including:

1. Early design and pilot before full implementation.

2. Need for some centralization and responsibility for data production and maintenance.

3. Need for a centralized high-end computing facility with a distributed system design to meet state needs including off-site archive of documents.

4. Need to determine to what extent each state or Bay Program partner will participate in providing local knowledge and capabilities for the full range of activities under this proposal.

5. To manage the data center and remote sensing activities, the Expert Panel discussed staffing requirements and concluded that at a minimum it should have the following staff level. In addition, it was suggested that as data centers in each state come on line, they will require similar levels of staffing.

   a. One Manager
   b. One Network Specialist/System Administrator
   c. Two Programmers
   d. Two Data Technicians

The most important infrastructure components are collaboration, cooperation and commitment. They will be required in each federal agency and especially the states to make this distributed model work.

SECTION XI - OPERATIONAL RESEARCH AND DEVELOPMENT

As noted throughout this document, the Expert Panel discussions resulted in several action items for operational research and development projects. A list of those projects is provided for future reference and prioritization by the Bay Program partners. There are many opportunities to form partnerships to conduct this research. The University of Maryland at College Park was recently awarded a NASA grant to establish a Regional Earth Science Applications Center. This center should be engaged by the Bay Program Office to advise on remote sensing needs. In addition, NASA will issue a research announcement this year that is geared toward state and local governments. This program could provide the necessary research funds to develop remote sensing tools that meet the requirements of the Bay Program. We also have many opportunities, working with our DOD partners, to develop the operational remote sensing tools needed. Managing these efforts will be a formidable task and will require the attention of dedicated staff.

6. Improved Classification of multi-date Landsat TM imagery to obtain Anderson Level II Results especially with regard to Agricultural Crop Practices.

7. Developing methods to deal with crop rotation practices.

8. Conducting research on better methods to identify palustrine wetlands with special emphasis on forested wetlands.

9. Develop a methodology to detect gains in wetlands that complements the cross-correlation method for wetlands losses.

10. Evaluate 1-meter to 6-meter satellite data for targeted high resolution needs.

11. Develop a methodology for land use classification starting with the needs (model driven) and determine if the locally produced data will provide the required input.

12. Perform model-driven requirement case studies of existing vs new data sets.

13. Develop cost-effective accuracy assessment methods.

14. Determine the level at which accuracy reporting needs to be conducted (e.g. county, state or federal).

SECTION XII - SUMMARY

The Expert Panel provided an invaluable service to the Bay Program by “debunking” many of the myths about remote sensing capabilities. They also cautioned Bay Program participants to not become seduced by high resolution products. They come with high costs and generally require significantly longer production times, in addition to the fact that they can result in an “overkill” for certain applications. These wise words provided a much needed reality check. We are now left with the formidable task of gaining a consensus opinion among the partners to proceed with implementation of the program outlined in this document.

The proposed model is both complex and costly. There must be a commitment that is solidly supported by all partners for this approach to work. Anything less will result in another failed attempt to monitor the health of the Chesapeake Bay over the coming decades.

SECTION XIII - REFERENCES

Original 24-page Discussion Notes from Expert Panel Assembled by the Chesapeake Bay Program Office, January 27 -28, 1999.

Working Notes/Minutes of the Expert Panel Deliberations as captured by Joe Macknis, EPA Bay Program

Dobson, J. E. et al., April 1995, NOAA Technical Report NMFS 123, NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation

Verbyla, D. L., 1995, CRC Lewis Publishers, Satellite Remote Sensing of Natural Resources

EPA Wetlands Home Page
http://www.epa.gov/ceisweb1/ceishome/atlas/wetlandsx/results_to_date.htm

Space Imaging Carterra Imagery Product Information Home Page
http://www.spaceimage.com/home/products/index.html

Short, Sr., N. M., "The Remote Sensing Tutorial" Remote Sensing and Image Interpretation & Analysis, http://rst.gsfc.nasa.gov/TofC/toc1.html

President's Clean Water Action Plan
http://cleanwater.gov

Day, R.L., Richards, P.L., Brooks, R.P., *Chesapeake Bay Riparian forest Buffer Inventory*, Final Report, March 13, 1997, The Pennsylvania State University

APPENDIX A.
PANELISTS

Dr. Tom Loveland
EROS Data Center, USGS
Science and Applications Branch
47914 252nd St
Sioux Falls, SD 57198
Voice: 605-594-6066
Fax: 605-594-6529
loveland@edcmail.cr.usgs.gov

Dr. Chris Justice
Department of Environmental Science
Clark Hall
University of Virginia
Charlottesville, VA 22903
Voice: 804-924-3197
justice@virginia.edu

Dr. Vic Klemas
College of Marine Studies
University of Delaware
Newark, DE 19716
Voice: 302-831-8256
Fax: 302-831-6838
klemas@udel.edu

Dr. Greg Koeln
Earth Satellite Corporation
6011 Executive Boulevard
Suite 400
Rockville, MD 20852
Voice: 301-231-0660
Fax: 301-231-5020
gkoeln@earthsat.com

Dr. Sam Goward
Geography Department
2181 LeFrak Hall
University of Maryland
College Park, MD 20742-8255
Voice: 301-405-4050
sg21@umail.umd.edu

Dr. John M. Morgan
Geography Department
Towson University
Baltimore, MD
Voice: 410-830-2964
Fax: 410-830-3888
jmorgan@towson.edu

Dr. Stephen Prince
Director, Mid Atlantic Regional Earth Science Applications Center Consortium
Geography Department
University of Maryland
College Park, MD 20742
Voice: 301-405-4062
sp43@umail.umd.edu